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FORESTRY ON THE BILTMORE ESTATE
Biltmore, N. C.

By E. H. Frothingham, Senior Silviculturist

Foreword

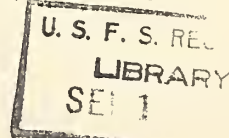
The Biltmore plantations are about all that is left of what Gifford Pinchot once called "the first practical application of forest management in the United States".

The plantations covered not more than three thousand of the many thousand acres under management. Their age, the history of their success or failure, and the many species tested, today give them a special demonstrational value. The Estate presents other items of interest to foresters: the native forest, the extensive planting for decorative and other purposes, and the game and wildlife populations.

A review of plantation conditions, based upon the results of a study completed in 1924, was issued as U.S. Dept. Agr. Misc. Pub. 61, Forest Plantations at Biltmore, N. C., by Ferdinand W. Haasis. This publication is now out of print; the following brief summary partially takes its place.

R. E. McArdle

R. E. McArdle,
Director.



THE ESTATE

The Estate was built up from many small holdings of farm and timberland by the late George W. Vanderbilt, beginning about 1889. The mansion was built between 1890 and 1895. By 1893 an area of 7,282 acres, 54 percent forest, had been acquired, and at the time of Mr. Vanderbilt's death, in 1914, the Estate had grown to about 100,000 acres. It extended about 20 miles southwesterly, along the ridges north of the French Broad River, in Buncombe, Haywood, and Henderson Counties, N. C., to beyond Brevard, in Transylvania County. Many miles of road and trail were built, giving access to Mount Pisgah and other scenic spots and to tributaries of the French Broad River.

Between 1916 and 1922 an area of 80,381 acres was sold to the Federal Government, becoming part of the Pisgah National Forest.* Another sale, of 1500 acres, was made in 1921 to the Biltmore Estate Company. This transfer carried with it a considerable area of forest plantations, parts of which can still be seen within the town limits of Biltmore Forest. The present area of the Estate is about 12,000 acres. It has nearly 140 miles of roads and trails, including 17 miles of macadam road.

Although the Estate contained, when acquired, a few small stands of virgin hardwood timber (including one of the finest, at Lookingglass Rock, to be found anywhere in the Southern Appalachian region), much of the woodland was overcut, or badly burned, or overgrazed. Some of the cleared fields were badly eroded.

FORESTRY PERSONNEL AND ACCOMPLISHMENTS

The general purpose of the forestry work on the Estate was to build up a forest combining utility, beauty, game habitats, and hunting grounds. The program included improvement of the native forest, and planting. In accordance with the plan for landscaping the Estate, under the direction of Frederick Law Olmsted and later of his assistant, C. D. Beadle, who is the present superintendent of roads and grounds, the earlier planting, particularly along the main roads, was largely for decorative purposes. The Douglas plantation, in 1890, briefly described further on, was the first substantial

*The cutting rights on this area had previously (in 1912) been contracted to the Carr Lumber Company, of Pisgah Forest, N. C., for a period of 20 years. The cutting was actually completed in ~~1928~~.

forest planting. The large variety of native and foreign trees and shrubs planted under the direction first of Mr. Olmsted and later of Mr. Beadle constitutes, in effect, a notable arboretum.

Forestry was taken up by Mr. Vanderbilt in 1892, upon the insistence of Mr. Olmsted. The first forester, appointed upon the recommendation of Charles Sprague Sargent, was Gifford Pinchot, newly returned from forestry training in Germany and France. Pinchot employed Henry Solon Graves as a field assistant. The early work, in 1892 and 1893, is described by Pinchot in a booklet, "Biltmore Forest", prepared for the Chicago Worlds Fair of 1893. This booklet outlines a working plan for the 7,282 acres then in the Estate. For the part of the Estate east of the French Broad River the system of management adopted was high forest (clear-cutting blocks in series, for sustained yield). West of the French Broad the system was selection, localized to obtain the yield from one-fifth of the area during each period of five years. Ninety-two compartments averaging 42 acres were laid out. They were separated by topographic features and old woods roads, and formed three blocks, one on the west and two on the east side of the French Broad. A rotation age of 150 years was adopted, and improvement cuttings were made. A nursery was installed on the Swannanoa River bottoms in 1892 or 1893, and planting of the cleared and often eroding fields was started.

In 1895 Pinchot was succeeded as forester by Dr. C. A. Schenck, who was recommended for the place by Sir Dietrich Brandis. Dr. Schenck continued the forest management of the Estate as it expanded in size, his operations extending to the vicinity of Brevard. Schenck's cuttings were of considerable variety, but in the main they were improvement cuttings, limited by exacting commercial requirements and by inadequate funds for non-commercial cultural treatment. Unfortunately no records are available from which the results of these cuttings can be traced with any degree of reliability. Those on the 80,381 acres sold to the government have been obliterated by the subsequent lumbering.

Early in his administration, Dr. Schenck was made president of the Biltmore Lumber Company, operating at Asheville what was said to be "the only band-mill in western North Carolina". Efforts to drive logs down the French Broad River to Asheville were abandoned.

By 1896 Schenck had five or six assistants, among them Overton W. Price, serving without pay for the training. This led, in 1898, to the establishment of the Biltmore Forest School, with headquarters on the Estate until 1909 when Schenck left. Since his departure, the Estate has been without a forester; cuttings for fuelwood

and other locally needed products have not followed the management plans previously in force, though it is understood that they have been conducted with reference to the maintenance of a constant supply.

THE PLANTATIONS

Records as to the total area planted are lacking. If the replanting of early failures is included the total might be as high as 3,000 acres, but it is probable that well-marked stands of planted timber never covered more than 1,000 acres. Some good stands have been cut to make way for agriculture, and many were on the land that was sold.

The purpose of planting, in accordance with Mr. Vanderbilt's desires, was apparently two-fold: (1) to conceal bare and eroding slopes and furnish attractive borders to the Estate roads; and (2) to contribute to the building up of a forest estate on European lines. Following the Douglas planting, in 1890, some plantations were established by Pinchet; but the majority were set out by Schenck. Between 1909 and 1912 some further planting, of Norway spruce, was done by Mr. Beadle. Some 40 different tree species have been used, about half of them conifers and half hardwoods.

Dr. Schenck's first efforts were with native species, mostly hardwoods. These appeared to have failed, for one reason or another, and Schenck then turned to white and shortleaf pines for the bulk of his planting. Some of the original hardwood plantings that were replanted with pine still exist as a suppressed understory. Of the 380 acres of plantation described by Haasis in "Forest Plantations at Biltmore, N. C." (U. S. Dept. of Agr. Misc. Pub. 61), 144 acres are pure or nearly pure white pine, and lesser quantities of this species are found on 180 acres of other plantings. Shortleaf pine, in greater or less quantities, occurs on 216 acres of plantation.

The following summaries apply to a few of the more noteworthy plantations. Except for the stands in which the Appalachian Forest Experiment Station is conducting thinning experiments, no measurements have been made since 1924.

Douglas Plantation

These are the oldest plantings, dating from 1890, and contain the largest trees. The scattered stands cover about 300 acres. The planting was contracted to the Douglas Nursery Company of Waukegan, Ill., for \$55 an acre, with guaranteed survival of 1100 trees per acre, second year. The contract specified planting stock 10" to 16" in height; on each acre planted the minimum percent by species was designated as white pine 75, Douglas fir 4, yellow birch 5, chestnut 5, the remaining 11 percent to be of hemlock, spruce, or any one or more of seven or more other species. The planting was on plowed strips. Schenck objected to the large growing space given the individual trees; "early returns cannot be obtained by way of thinning". The wide spacing, however, has resulted in good crown and bole development. In 1924 there were about 400 white pines per acre, the dominants 59' - 72' high and 11" - 16" d.b.h. Stands along main roads were pruned in 1920 or earlier, often to a height of 20'.

Long Ridge Plantation

This is a complex plantation occupying the conspicuous ridge that faces the traveller, after leaving the Biltmore gate, as he reaches the first open field. It covers 45 acres. The planting site was steep, bare, and badly eroding. Planting was as follows:

Winter of 1895 to spring of 1899: By three direct seedings at different dates, 31 acres were sown to hardwoods: white, red, and chestnut oaks, chestnut, hickory, black walnut, and buckeye; about 6.5 bu. of seed were sown per acre. Four acres were planted with 1 to 4-year-old black cherry, Douglas fir, sugar maple, white oak, hickory, ailanthus, chestnut oak, butternut, and black walnut; and 15 acres with 1 and 2-year-old seedlings of white, red, and chestnut oaks, ash, black walnut, hickory, and buckeye, named in order of quantity planted, and 400 10-year-old seedlings of Frazer fir and red spruce. Spacing was close, the number per acre varying from 6,000 to 7,000. Since the aggregate area reported for these plantings is larger than the area of Long Ridge as a whole, the plantings may have overlapped.

Spring of 1900: A general replanting, to conifers, of about 40 acres previously planted or sown to hardwoods. Species: white pine (79 percent) western yellow pine, shortleaf pine, Norway spruce, balsam fir, white fir, Douglas fir, Siberian and Japanese larch, Nordmann fir, jack pine, Swiss stone pine, and blue spruce. Average number per acre, 1890. On 5 acres of freshly abandoned field, 3,000 white oaks 4 years old were planted in rows alternating with rows of white pine (middle of west slope of Long Ridge); 10,000 balled 6-year-old shortleaf pines were planted to obliterate old roads.

Fall of 1900 to spring of 1905: Four reinforcement plantings and one seeding were made. The plantings were largely with white pine, the seeding with walnut.

This plantation is so complicated that it is difficult to get more than general impressions from it. On the whole, it gives the appearance of a pure stand of white pine, most of the other species occurring as isolated individuals. On the east slope Scotch and shortleaf pines may form as much as 25 percent of the stand. Douglas fir appeared to be doing well in 1915, not so well in 1924, very poorly today. Some of the scattered chestnut and white oaks and black cherries are quite large and thrifty, but the small sugar maple planting on the west slope has been almost at a standstill for the past 15 or 20 years.

In 1924, dominant trees of the different species had the following dimensions:

Species	Height	D.b.h.	Species	Height	D.b.h.
	ft.	in.		ft.	in.
White pine	45	8(6-10)	Black locust	46	7(5-9)
Shortleaf pine	36	6(5-7)	Black walnut	45	7(6-8)
Scotch pine	45	7(6-7)	Douglas fir	26	5(3-6)
Yellow poplar	45	7(4-9)	Sugar maple	36	3(2-5)
Black cherry	48	9(7-11)	Norway spruce	28	4

Swannanca Plantation

Two acres, planted in the spring of 1896, on the hill to the left, across the first open field after leaving the Biltmore gate. The site, an abandoned field, north exposure, with "good soil which was very easy to work" (Schonck). On 0.8 acre 2-year-old black cherry was planted pure; on 1.3 acres 3-year-old sugar maple, black walnut, and butternut were planted mixed, in proportion of 46, 35, and 19 percent, respectively. The planting was in previously prepared holes spaced 3' by 3', or about 5,000 per acre.

The cherry plantation is a failure, the trees poor, small and crooked. The other species have done fairly well; they are now in about the proportion of sugar maple 90, black walnut 6, and butternut 4 percent. The dimensions of the dominant trees in 1924 were:

Species	Height	D.b.h.
	ft.	in.
Black cherry	18 (15-23)	3 (2-4)
Sugar maple	43 (39-48)	6 (4-7)
Walnut and butternut	34	5

Old Orchard Plantation

This stand is west of the Swannanoa plantation, on a slope to the left, across the first open field after leaving the Biltmore gate. The site was an abandoned field with deep but badly eroding soil. In 1899, 5 acres (stand 1) was planted with 1 and 2-year-old seedlings of ash (42%), white oak (30%), red oak (13%), chestnut oak, buckeye, and black walnut; and 7 acres (stand 2) with 3 and 4-year-old white pines, those 4 years old partly from Germany. The plants were set in the downhill corners of spade-made holes, at the rate of about 4700 per acre in stand 1, 3800 in stand 2. The hardwoods did not do well and were reinforced a few years later with 1-year-old seedlings of yellow pine (mostly pitch pine). The latter averaged 30 feet in height in 1922, while the slightly older hardwoods were about 12 feet high. In the same year the white pine in stand 2 averaged 35 feet high. More about the growth of the white pine stand will be found in the discussion of thinning experiments.

Approach Road Plantation

This 6-acre plantation affords a good example of the overtopping of planted hardwoods by pine of a later planting, a result to be frequently observed in the Biltmore plantations. The area, was planted with 2-year-old black cherry and 3-year-old yellow poplar in 1895, by Pinchot; with white pine (nursery grown 4-year-old stock and wildings 2 to 4 feet high) in 1896, by Schenck; and with a large number of 1-year-old shortleaf pine seedlings in 1905, by Schenck. The spacing of the hardwoods was 4' by 4'. Although the dominant hardwoods in the present stand include some of the best planted yellow poplars at Biltmore, they occur as isolated individuals and groups in a stand that is mainly pine. Average dimensions of the dominants in 1922, by species, are as follows:

Species	Height	D.b.h.
	ft.	in.
Yellow poplar	42 (34-48)	7 (5-8)
Black cherry	40 (34-45)	5 (4-6)
Shortleaf pine	32 (24-41)	5 (3-8)

Spruce Plantation

Skirting the Long Ridge, Old Orchard, Swannanoa, and Approach Road plantations, the spruce stands are across the field to the left of the Swannanoa Road from the Biltmore gate. This, the youngest of the plantations, was planted by Mr. Beadle in 1911. The age of the Norway spruce planting stock is not known. The planting is in five groups, 23 acres in all, not far apart but differing in site quality. The average height of the dominant trees in 1921 varied between 10 and 19 feet and their diameters between 1 and 4 inches. The stands today appear generally very thrifty.

Old Dairy Plantation

About 12 acres are covered by this stand, which is south-east of the Swannanoa plantation, west and across the creek from the Service Road. Eight acres are essentially pure shortleaf pine, with mixtures of white pine and sugar maple in places. About 4 acres are in white pine. When it was planted, in 1903, the area had been in use 10 years as a cow yard, and there was some erosion. The white pine planting stock was 4 years old; the age of the shortleaf pine stock is not known.

Ferry Farm Plantation

This plantation is north of the Ferry Road and north and west of its junction with the Dairy and River roads. It is separated from the Ferry Road by a narrow strip of Douglas white pine plantation. Of 22 acres planted, only 16 are accounted for in the later records. The planting was done in the spring of 1900, with reinforcements in 1901-2. In the first planting 78,000 2-year-old white and 10,000 1-year-old pitch pines were used (4,000 per acre). They were planted in spade-made holes, a few handfuls of rich soil from nearby swales

were placed about the roots, and a stone was put close to the stem of each plant. The reinforcements were with white and yellow pines, the latter probably shortleaf. Characteristics of a part of this stand, from 1916 to 1936, are discussed under the heading, "Thinning Experiments". The dominant white pines are shorter than the dominant shortleaf pines, and shortleaf has so generally outgrown white pine that the stand on a thinned plot, in which white pine has been definitely favored, has become almost pure shortleaf pine.

Rice Place Plantation

A 35-year-old planted stand of white oak is the principal feature of this 12-acre plantation, which is less than a mile from the Long Shoals gate of the Estate, on the road along the French Broad River. From 1903 to 1905, ash, sugar maple, white oak, and yellow pine were planted here at the rate of about 3,420 per acre. Existing records of the different plantings are very incomplete. They could not be identified in 1922, and the stand descriptions made then are independent of the planting dates. At that date, the white oak, 18 years old, in one nearly pure stand of about 2 acres averaged 25' high and 2" in d.b.h.; the average height of the dominants was 30' and their average diameter 5". White ash in mixture with the oak is taller - 32'-34'. Haasis' comment was "judging by these stands, ash may be expected to make better growth in mixture with oak than when planted pure, but oak apparently will do better when ash is not mixed with it". The white oak stand is dense and the trees are slender. In addition to the sprinkling of ash the stand contains a few volunteers, some of them large, of river birch, yellow poplar, beech, and persimmon.

Apiary Plantation

This plantation is west of the French Broad River, about 1-1/2 mile from the Ferry and about 1/4 mile southeast of Sheep Farm Road on an old woods road from the latter. The identity of the separate plantings with the present well-marked stands is indefinite because of planting failures, replantings and overlaps. The present stands cover about 21 acres.

The planting site was an abandoned field of poor stony soil covered with beard-grass, but with a small patch of good soil near the site of an old farm house. In the spring of 1897 Schenck planted

15 acres (in furrows) with locust (48%), hickories (14%), black cherry (10%), white pine (9%), sugar maple (5%), basswood, black walnut, yellow buckeye, Douglas fir, silver fir, Siberian larch, blue spruce, Norway spruce, and Sitka spruce, at an average rate of about 3,000 per acre. In the fall of the same year he made a direct seeding of 19.5 acres, largely a reinforcement of the spring planting, using white oak (43 bu.), hickory (16 bu.), chestnut oak (9.5 bu.), and chestnut (0.5 bu.); and in the fall of 1898, 24 bu. of chestnuts were planted on 4 acres to complete the above planting. In the spring of 1899, 500 sugar maples (7 years old) and 1000 white pines (2-year-old wildlings) were planted to fill blanks, and a year later the earlier plantings were reinforced with 24,000 each of white pine (2 years old) and pitch pine (1 year old).

Of the 11 well-marked Apiary stands described in 1921-22 by Haasis, two are of special interest because they contain the thinning experiments, started in 1916, which will be described under the next heading. These are Stand 3 (sugar maple and white pine), 0.4 acre, and Stand 4 (white pine), 2.0 acres. Stand 5 (black cherry), 0.2 acre, which is adjacent to Stand 4 and partly in the isolation strip of thinned sample plot 4a, is also of interest because of the development of the cherry, whose dominant trees, in 1924, were from 53' to 55' high and from 9" to 10" in diameter. The cherry has good wood development but rather poor form; it has overtopped and suppressed rows of planted white and chestnut oaks.

THE THINNING EXPERIMENTS

Following the abandonment of systematic forestry activities on the Estate in 1909, the plantations have received none of the cultural treatment that many of them needed very badly. Stands bordering the principal roads have been pruned and freed of dead trees, but the numerous plantings that grow into overdense stands have been left to stagnate or to thin themselves by natural competition, with a heavy loss through mortality and probably also in quality and condition of the ultimate mature forest. Systematic thinning should have followed the very dense planting used in much of Schonck's work; and this, indeed, was his intention if the forestry program had continued. These dense stands presented such good opportunities for experiments to determine the rate of growth in thinned as compared with unthinned planted stands, and to study the changes in the stand incident to growth and competition, that in 1916 the Forest Service, in

cooperation with the Biltmore Estate, began such a study with the establishment of four groups of small plots. Since 1921 the experiments have been continued by the Appalachian Forest Experiment Station.

The plots were small and the experiments limited in scope because of the lack of uniformity of stand and site conditions over large areas. Two of the experiments are in pure white pine stands in the Old Orchard and Apiary plantations, respectively, one in a mixture of shortleaf and white pines in the Ferry Farm, and one in mixed sugar maple and white pine in the Apiary plantation. In all of these the first thinning was done in October, 1916, a second in the winter of 1922-3, a third in the dormant season of 1928-9, and a fourth in the spring of 1936. At, or about, the time of each thinning, measurements were made of all trees to be cut or left standing on the thinned plots and of all trees on the unthinned control plots, by species and crown classes. The numbers of growing seasons between the dates of measurement were 5 for the first period, 7 for the second, and 7 for the third, a total of 19. At the start, each tree was given a number so that its history, and the history of like groups, could be followed throughout.

Some general results of the thinnings are presented in the following summaries. Growth, salvage and growing stock are expressed, for the white pine plots, in standard cords per acre of pooled wood to a minimum top diameter of 4" inside bark in trees 4.2" d.b.h. and larger; and for the other plots in square feet of basal area per acre in all trees.

Thinnings in Pure White Pine

The Old Orchard and Apiary plantations, in which the two white pine thinning experiments are being conducted, differ in several respects. The Old Orchard was planted in March, 1899, the Apiary in the spring of 1897. The number of trees planted per acre varied between 3200 and 3500 in the Old Orchard and between 4400 and 4800 in the Apiary. In the latter, however, there is evidence that 2-year-old American stock from the Biltmore nursery was planted in alternate rows with 4-year-old German stock, and that the plants from one source or the other, presumably the younger American stock, soon became subordinate. In 1916, when the thinning plots were established, most of the trees in every other row of the Apiary plots had died. The mortality per acre between the dates of planting and of the first thinning was 3,000 in the Apiary plantation (20 growing seasons) as compared with only about 850 in the Old Orchard (18 growing seasons). The develop-

ment of the Apiary stand was strongly influenced by this heavy reduction in the number of trees.

Furthermore, the part of the Old Orchard plantation in which the thinning plots are located is on a north-facing slope with a considerable range of moisture conditions and a corresponding variation in the heights of the dominant trees, while the Apiary plots are on level ground and the dominant heights are very much more uniform. Again, the thinning of the Old Orchard plot has been under control from the start, while the Apiary plot suffered some unauthorized cutting in 1922. These differences have combined to give quite different results from the two experiments. For example, in the Apiary plots the present volume per acre of the unthinned plot is much in excess of that of the thinned plot, while in the Old Orchard group the volumes are nearly equal.

The Old Orchard Thinnings

The area of Plot group 1, in the Old Orchard white pine plantation, is about an acre and a half, including a quarter-acre thinned plot (Plot 1a), two one-eighth acre unthinned controls (Plots 1b, c), and isolation strips. Because of site differences from one end of the group to the other, the control was divided into two parts, one at each end of the thinned plot; the two controls combined had about the same number of trees in 1916, and about the same basal areas and volumes, as the thinned stand, and so the figures for the successive dates of measurement and thinning have been combined for comparison with those of the thinned plot. While each of the control plots is relatively uniform as to site, there is considerable variation within the thinned plot, which has therefore been divided into four sub-plots.

Table 1 presents some of the characteristics of the thinned and unthinned plots at the time of the first and the latest thinning:

Table 1.- Characteristics of Old Orchard white pine plots
at time of first and latest thinning

	Thinned Plot 1a				Unthinned Plots 1b,c	
	1916		1936		1916	1936
	Before Thinning	After Thinning	Before Thinning	After Thinning		
No. of trees per acre (total)	2304	1136	368	312	2584	1040
Avg. d.b.h., inches	3.5	4.1	7.9	8.2	3.3	5.6
Avg. height, dom- inants and co- dominants, feet	34	38	58	59	33	46
Basal area per acre, square feet	153	106	126	113	157	175
Volume per acre of wood 4" i.b. and larger in trees 4.2" d.b.h. and larger, standard cords	8.2	7.6	27.8	25.3	7.6	28.9

The total quantity of wood removed in the four thinnings was 2170 cubic feet, computed as the entire stem volume, without bark. Thirty-eight percent (9.1 standard cords) was wood 4" and over in diameter, inside bark. This salvage includes the intermediate growth of the trees cut. The remainder of the growth of the stand was, of course, that of the trees left standing after the 1936 thinning. This amounted to 20 cords of 4" wood per acre in the thinned plot, 21 cords in the unthinned control, or an annual average of a little more than a cord in each during the 19 growing seasons that elapsed between the first and the latest thinning. Combining salvage and growth, the total production per year was 1.5 cords per acre for the thinned as against 1.1 cords for the unthinned plots.

When the 1936 volumes of the thinned plot (after thinning) and of the unthinned controls, shown in Table 1, are compared, the latter is seen to have an advantage of about 14 percent. This quantitative advantage, however, is offset by the fact that 65 percent of the 1936 volume of the thinned stand is in trees 8" d.b.h. and over, and 25 percent in trees 10" and larger; while in the unthinned plots the corresponding percentages are only 40 and 12. Thus with only a relatively small deficit in total volume of growing stock, the thinned stand is markedly superior in quality, while its yield in wood removed in thinning represents a past yearly advantage of nearly half a cord per acre.

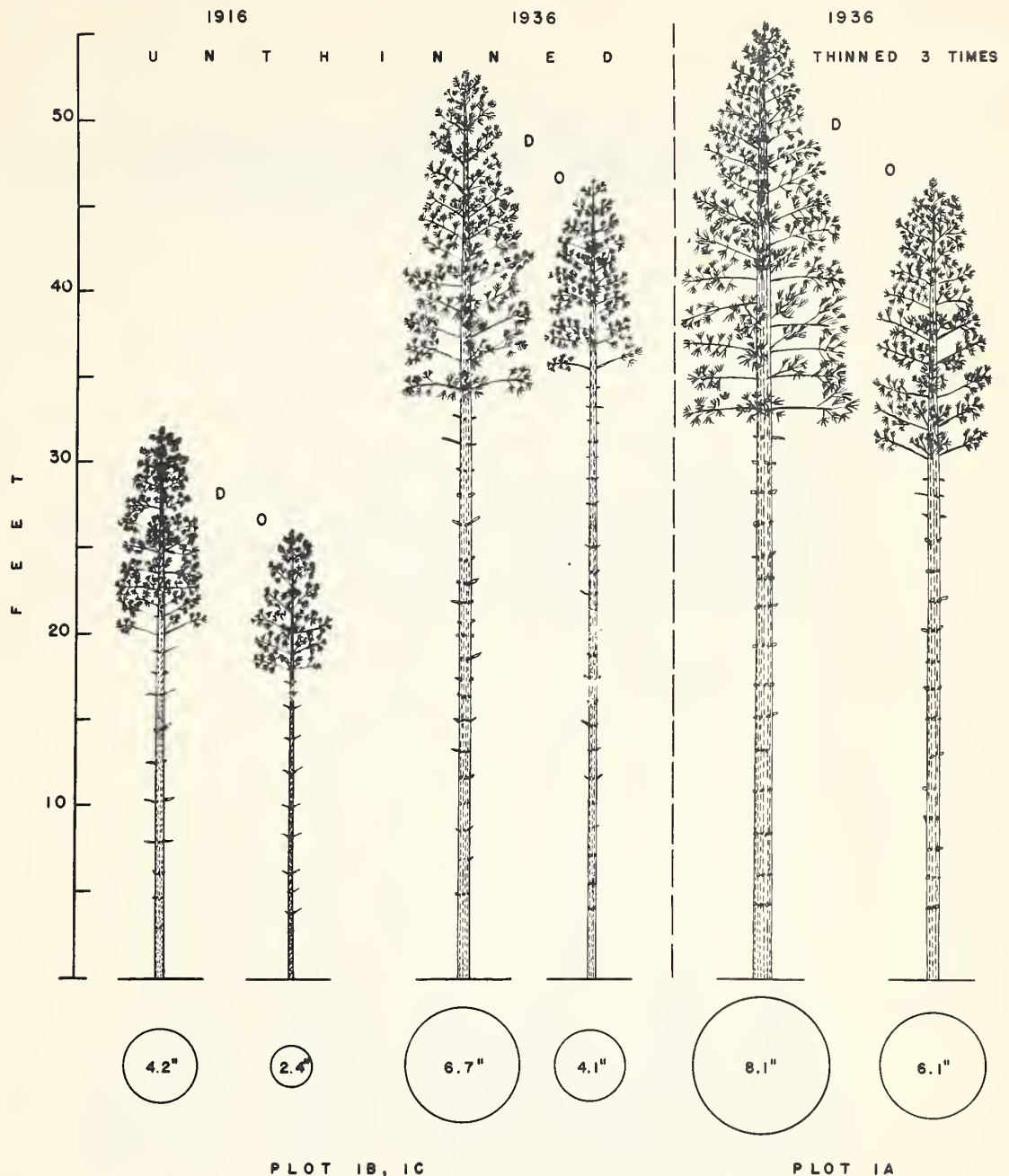
The diagrams on Pages 15-16 bring out advantages for the future growth of the thinned stand that have resulted from thinning. Both diagrams are drawn to scale. In the thinned plot, 75 percent of the trees were dominant or codominant before thinning in 1936, as compared with only 42 percent in the unthinned plots. In the thinned plot, also, the tree crowns are longer and more vigorous. Measurements of 185 trees in the Old Orchard and Apiary plots gave the following average relations between crown ratio (ratio of crown length to total height) and growth percent in basal area for the different crown classes:

Crown Class	Crown Ratio		Growth Percent in Basal Area		Basis, trees	
	Thinned	Unthinned	Thinned	Unthinned	Thinned	Unthinned
Dominant	.51	.41	9.19	7.71	51	35
Codominant	.31	.30	6.89	5.20	40	18
Intermediate	.27	.23	6.07	3.41	18	11
Overtopped	—	.11	—	2.20	—	12
All	.40	.31	7.83	5.62	109	76

The more rapid growth associated with large crown ratios promises soon to raise the growing stock volume of the thinned stand to, or above, the level of that of the unthinned controls.

BILTMORE THINNINGS, WHITE PINE

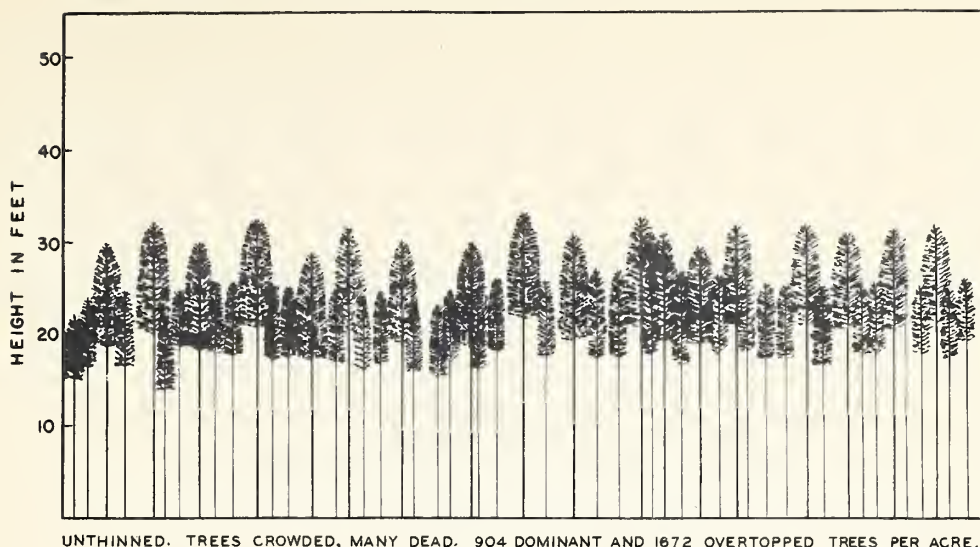
COMPARING THE HEIGHTS, CROWN LENGTHS, AND DIAMETERS, OF THE AVERAGE DOMINANT (D) AND OVERTOPPED (O) TREES IN-



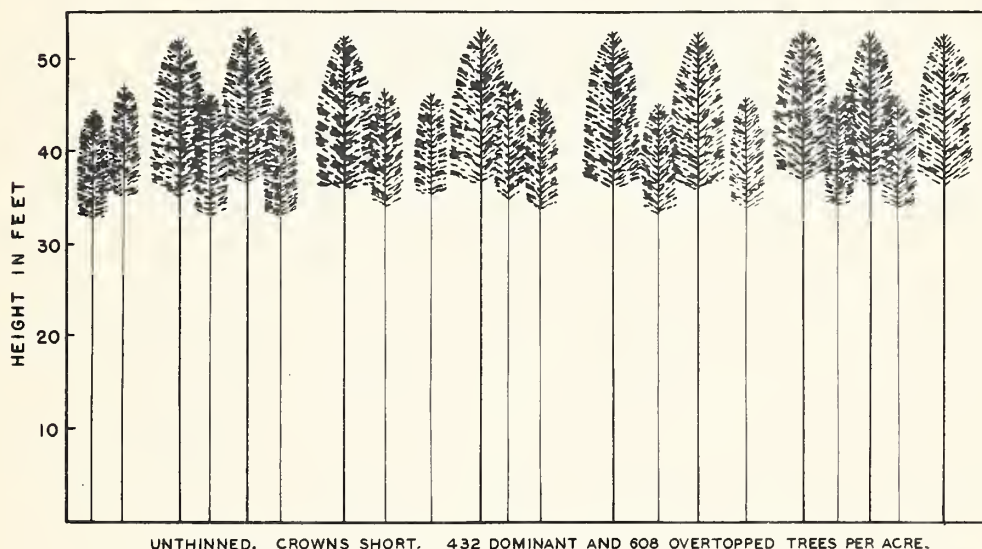
IN 1936 THE THINNED STAND, WITH ONLY 35 PERCENT OF THE NUMBER OF TREES IN THE UNTHINNED STAND, CONTAINED 70 PERCENT AS MUCH WOOD VOLUME AS THE UNTHINNED STAND. WITH THEIR LONGER CROWNS THE TREES IN THE THINNED STAND WILL GROW MORE RAPIDLY.—THE GREATER MASS OF FOLIAGE POSSESSED BY EACH TREE WILL PRODUCE A LARGER QUANTITY OF FOOD MATERIAL

IN THIS AND THE ACCOMPANYING DIAGRAM THE TERM "DOMINANT" (D) IS EXTENDED TO INCLUDE THE CODOMINANT TREES, AND "OVERTOPPED" (O) TO INCLUDE THE INTERMEDIATE TREES.

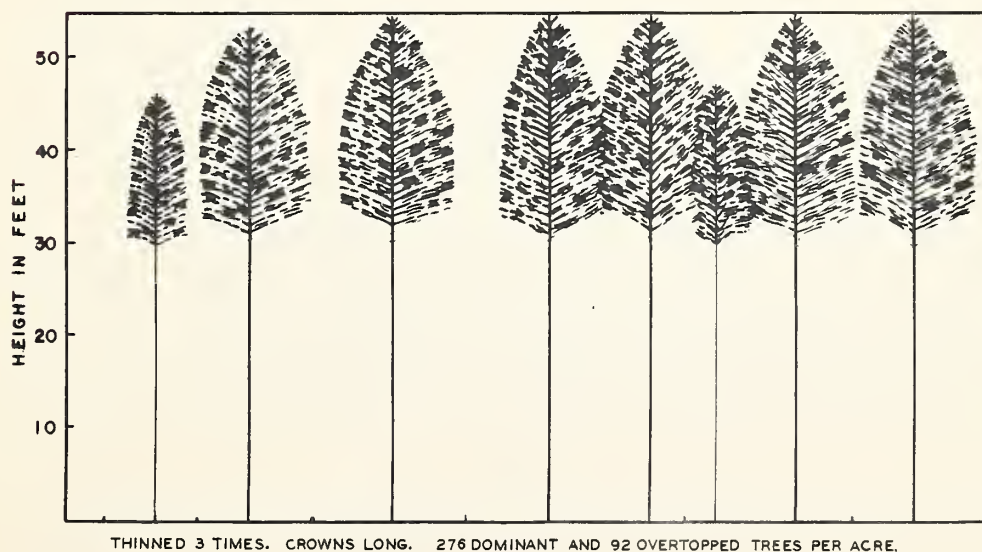
BILTMORE THINNINGS, WHITE PINE, PLOTS 1-A, B, C



1916



1936



1936

The Apiary Thinnings

Thinned Plot 4a, in the Apiary plantation, is 1/8 acre in size while its unthinned control is 8/100 acre. The characteristics of the two plots in 1916 and 1936 are shown in Table 2:

Table 2.- Characteristics of Apiary white pine plots at time of first and latest thinning

	Thinned Plot 4a				Unthinned Plot 4b	
	1916		1936		1916	1936
	Before Thinning	After Thinning	Before Thinning	After Thinning		
No. of trees per acre (total)	1760	952	296	248	1425	575
Avg. d.b.h., inches	4.7	5.4	9.3	9.6	5.1	8.6
Avg. height, dominants and co-dominants, feet	41	45	64	65	44	61
Basal area per acre, square feet	210	152	139	126	204	234
Volume per acre of wood 4" i.b. and larger, in trees 4.2" d.b.h. and larger, standard cords	25.1	23.1	33.4	30.4	29.0	54.6

The total stem volume, without bark, removed in the four thinnings was 3200 cubic feet, of which 52 percent (18.6 standard cords) was wood 4" and over in diameter, inside bark. The trees left standing after the 1936 thinning produced 19.4 cords of 4-inch wood per acre during the 19-year period between the first and the latest thinning. In the control plot the growth in the

same period was 25.6 cords. In average annual growth the control exceeded the thinned plot by about 0.3 cord per acre. This was largely because of the heavy uncontrolled cut of 1922. If salvage is added to growth the total yearly production per acre averaged 2 cords for the thinned plot but only 1-1/3 cord for the control.

As shown in Table 2, the growing stock value per acre of the control plot in 1936 was more than double that of the thinned plot. The heavy 1922 cutting is chiefly responsible for this result, although it is partly the effect of the slightly better site and density conditions on the control plot evidenced by the greater height and smaller number of trees in 1916. In quality of the stand in 1936, the thinned plot, with 92 percent of its volume in trees 8" d.b.h. and larger, is somewhat superior to the control, which has only 77 percent of its volume in the larger size class. It is not likely, however, that the volume per acre of the thinned stand will ever equal that of the control.

Thinnings in Mixed Shortleaf and White Pines

This experiment is located in a part of the Ferry Farm plantation in which, in 1916, white pine formed from 30 to 50 percent of the stand, by number of trees. The remainder of the stand was principally shortleaf with a few pitch pines. During the 16 years prior to the establishment of the plots there had been an indicated mortality of from 15 to 25 percent. The stand before thinning was dense, with shortleaf pine decidedly in the ascendancy over the white pine.

The purpose of the thinnings was to free the best trees (regardless of species) from undue competition, and to encourage the continuance of a mixed stand by admitting light to promising white pines in the lower crown classes. Otherwise the white pine seemed doomed by the greater aggressiveness of the shortleaf. The thinnings have failed to reach this objective.

Each of the plots is 1/10 acre in size and their site qualities are approximately equal. There was no thinning in 1936; the third, and latest, was in 1929. The principal stand characteristics of the thinned and unthinned plots are compared in Table 3:

Table 3.- Characteristics of Ferry Farm shortleaf and white pine plots in 1916 and 1936

	Thinned Plot 2a		Unthinned Plot 2b	
	1916	1936	1916	1936
	Before Thinning	After Thinning		
<hr/>				
<u>No. of trees per acre</u>				
Shortleaf pine	2320	1230	460	1510
White pine	1040	870	290	1420
Both	3360	2100	750	2930
<hr/>				
<u>Avg. d.b.h., inches</u>				
Shortleaf pine	3.7	4.3	6.6	4.0
White pine	2.0	2.0	4.4	2.0
Both	3.3	3.5	5.8	3.3
<hr/>				
<u>Avg. height of dominants and codominants, feet</u>				
Shortleaf pine	25		47	46
White pine	18		44	46
Both	23		45	46
<hr/>				
<u>Basal area per acre, square feet</u>				
Shortleaf pine	174	123	108	135
White pine	23	20	30	45
Both	197	143	138	180
<hr/>				

During the growing seasons between 1916 and 1936, the rate of production (growth plus salvage) of the thinned stand was 10.5 sq. ft. basal area per acre per year, of which 8.8 sq. ft. was shortleaf and 1.7 sq. ft. white pine. The control plot, as a whole, made no growth in basal area, although the trees 6" d.b.h. and larger actually made considerable growth which was offset by the death of smaller trees. The thinnings not only increased the total production of the stand but also its quality, for of the basal area in 1936, 25 percent in the thinned stand was in trees 8" d.b.h. or larger, as compared with 10 percent in the control.

The thinning has so far failed in its attempt materially to increase the proportion of white pine in the upper crown classes.

Between 1916 and 1936 the increase in the number per acre of dominant and codominant white pines in the thinned stand was from 20 to 40, while in the control it was from 120 to 150. Apparently the more tolerant white pine could compete with the shortleaf more successfully in the dense than in the thinned stand; in both, the bulk of the upper crown class trees is still of shortleaf pine. The failure of the white pine is surprising, for as a rule shortleaf pine does not outgrow it. The cause is quite likely some initial advantage of the shortleaf, such as older or more thrifty planting stock.

Thinnings in Mixed Sugar Maple and White Pine

The best available location for thinning experiments involving sugar maple was a small stand in the Apiary plantation covering less than half an acre. Here Dr. Schenck had planted, in 1897, nearly equal portions of 5-year-old sugar maple and 2-year-old white pine in alternate rows. In 1916, when the thinning plots were established, the stand was 19 years old, and the mortality had been 55 percent. Thinned Plot 3a is 1/20 acre and control Plot 3b 1/30 acre in size. The stand characteristics are given in Table 4.

Table 4.- Characteristics of Apiary sugar maple and white pine plots in 1916 and 1936

	Thinned Plot 3a				Unthinned Plot 3b	
	1916		1936		1916	1936
	Before Thinning	After Thinning	Before Thinning	After Thinning		
<u>No. of trees per acre</u>						
Sugar maple	1560	860	580	420	1560	840
White pine	400	160	---	---	510	150
<u>Avg. d.b.h., inches</u>						
Sugar maple	2.6	2.9	4.9	5.4	2.7	4.2
White pine	4.5	5.4	---	---	4.6	7.6
<u>Avg. ht. of dominants and codominants, feet</u>						
Sugar maple	39		51			
White pine	39		--			
<u>Basal area per acre, square feet</u>						
Sugar maple	55	40	75	66	64	83
White pine	44	25	--	--	56	47
Both	99	65	75	66	120	130

This was to be primarily a sugar maple experiment. Upper crown class maples were favored by increasing their growing space. The maples, in 1916, were slender, and to reduce danger of their breakage by sleet and wind, many of the pines were left standing until the thinning of 1928, after which the thinned stand was pure sugar maple. This was at the expense of the best volume-producing element in the stand, and since the pine was left in the control plot the growth rate and growing stock of the latter are much greater than in the thinned plot.

Considering only the sugar maple, however, the thinned plot seems to be catching up with the control. Before the 1916 thinning the basal area per acre of the sugar maple in Plot 3a was 13 percent less than in Plot 3b while in 1936 it was only 10 percent less. In Plot 3b the proportion of white pine in the total basal area has diminished from 48 percent in 1916 to 36 percent in 1936.

The quality gain that has resulted from the thinnings so far, with respect to sugar maple, is evident from the fact that 12 percent of the maple basal area in Plot 3a after the 1936 thinning is in trees 8" d.b.h. and larger, while in Plot 3b there were no maples as large as 8".

